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Comparative Study of Treatment of Sago Wastewater using HUASB Reactor in the Presence and Absence of Effective Microorganisms

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Abstract

This study evaluates the performance of HUASB reactors in anaerobic treatment of sago industry wastewater using Effective Microorganism. A laboratory scale Hybrid Up flow Anaerobic Sludge Blanket (HUASB) reactor, having a volume of about 4.7 L was operated and Polypropylene rings were used as packing media. The initial OLR (Organic Loading Rate) range was about 0.75 Kg.COD/m^3.day and further increased. Various effluent characteristics like pH, COD, Total Suspended Solids, VFA, Alkalinity and biogas production were studied until the attainment of steady state. The pH of treated effluent during steady state condition was almost neutral for both reactors even though the influent had an acidic pH. The maximum COD and TSS removal efficiencies were as high as 88% and 77% in HUASB reactor in the presence of effective microorganisms with an OLR of 9 kg.COD/m^3.day as compared with HUASB reactor in the absence of effective microorganisms of 76% and 68% with an OLR of 9 kg.COD/ m^3.day during the steady state period. The gas production was increased with increased OLR. The maximum gas production of 2.8 L/d and 2.0 L/d for HUASB reactor in the presence of effective microorganisms and HUASB reactor in the absence of effective microorganisms were obtained.

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Keywords: Sago; HUASB reactor; effective microorganisms; biogas.

1. Introduction

Tapoica is generally known as Sago, the edible starch globules processed from the tubers of tapioca. Its Botanical name is "*Mannihotutilissima*".Sago is manufactured from root of tapioca. Tapioca root has a high resistance to plant disease and high tolerance to extreme stress condition such as periods of drought and poor soils. Roasted Sago is known as sago common and boiled sago as nylon sago. An anaerobic process is considered more suitable to treat high strength organic effluents. Anaerobic digestion like other biological processes strongly depends on mesophilic temperature range of 35°C and40°C and at about 55°C for the thermophilic range (Kim et al 2002). In this process, the organic fraction of the waste is segregated and fed into a closed container (bio gas digester). In the digester, the

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segregated waste undergoes biodegradation in presence of methanogenic bacteria and under anaerobic conditions, producing methane-rich biogas and effluent. Anaerobic digestion results in the conversion of organic matter into methane and carbon dioxide via series of interrelated microbial metabolisms under „septic‟ conditions. Anaerobic digestion can be operated in a wide range of temperatures (Van Lier et al., 1997; Batstone et al., 2002). The use of effective microorganisms for reducing volumes of sewage sludge has often been suggested as feasible (Higa, T. and Chinen, N., 1998) in either wastewater treatment plants or onsite waste water treatment systems such as septic tank and industrial effluents.

EM is a mixer of various groups of naturally useful living in the environment, not pathogenic, anaerobic microorganisms consisting basically from phototrophic and lactic bacteria and yeast (Freitag D.G., 2000). EM has the potential to improve the overall effectiveness and efficiency of the UASB reactor for the treatment of domestic wastewater (EI Karamany et al., 2011). A hybrid reactor is an anaerobic digester that combines an Upflow Anaerobic Sludge Blanket reactor with an anaerobic filter. Over the years, HUASB reactors have been used to treat waste waters from sugar industry (Coates and Colleran, 1990), pharmaceutical units (Henry et al., 1996 and, distilleries (Shivayogimath and Ramanujam, 1999). Another advantage is that, HUASB reactor needed lesser time for start-up and showed better removal efficiencies as compared to AF reactor using the same substrate of waste water (Rajakumar et al ., 2008). Although hybrid reactor design is expected to work efficiently without granular sludge, it is desirable to cultivate granular biomass (Tilche and Vieira, 1991).

2. Materials and methods

2.1. Composition of wastewater

The wastewater was collected and the collected sample was kept in a freezer at 4º C and was studied for its characteristics. The sago mill wastewater sample was analysed and the results obtained are shown in table 1.1.

Table 1. Characteristics of sago wastewater

Sr. No.	Characteristics	Observed Result
1.	pH	4.2 – 4.6
2.	Colour	Milky White
3.	TS	16300 – 16500
4.	TDS	8060 – 14260
5.	TSS	2240 – 8240
6.	VS	13570 – 14580
7.	COD	3000 – 5000
8.	VFA	440 – 450
9.	Chlorides	990 – 1010
10.	Acidity	900-1000

*All values are in mg/L except pH and Colour.

2.2. Seeding sludge

The seed sludge was collected from an anaerobic reactor treating sago mill wastewater and was used for the inoculation in the HUASB reactor. This was used as the inoculum because the sludge had sufficient number of acetogenic and methanogenic bacteria (Bischofsberger et al., 2005).

2.3. Reactor set-up

A lab scale Hybrid Upflow Anaerobic Sludge Blanket (HUASB) reactor of 4.7 litres capacity was fabricated for lab scale studies. It was fabricated using transparent acrylic fibre with a diameter of 10 cm and a height of 60 cm and with a wall thickness of 3 mm. Five sampling ports were provided along its length at equal distance. Inlet end opens towards the bottom of the reactor, so the feed strikes at the bottom. An outlet was provided at the top, which was connected to the effluent tank. The gas outlet was connected through rubber tubing to the liquid displacement system to measure the gas production. The amount of gas produced is equal to the amount of liquid displaced and hence gas produced can be measured at regular intervals of time.

A filter media of height 15 cm made of Polypropylene rings was provided at the middle of the reactor. About 16 rings were packed in the reactor for consistency. The surface area of each ring was $24.25m^2/m^3$ and the total surface area occupied by the packing was $388m^2$/m3. Thereactor setup was shown in fig.1.1.The reactors were operated at mesophilic temperature (27±5° C). The excess suspended solids (SS) in the reactor are wasted periodically and hence a constant SS values were maintained in the reactor. The wastewater comprising substrates, glucose, balanced nutrients and alkalinity were fed in the reactor using a peristaltic pump.

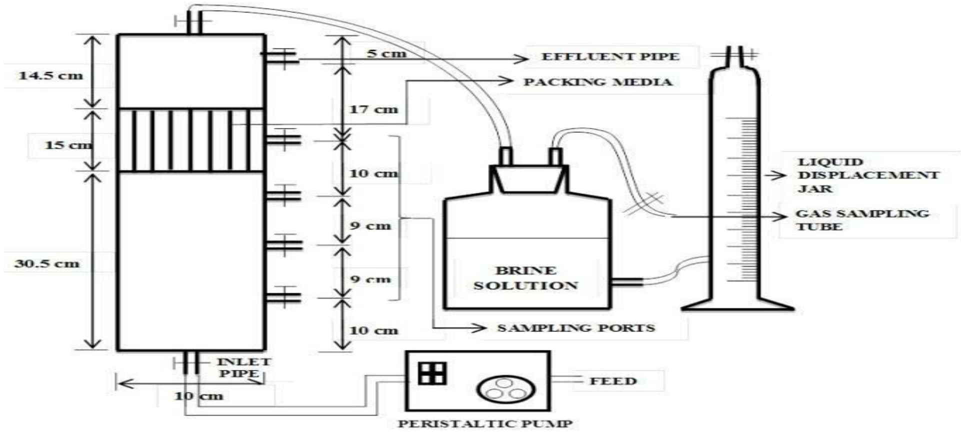

Fig.1. Schematic diagram of experimental setup of HUASB reactor

2.4. Inlet and outlet distribution systems

At the bottom, the feed inlet pipe of 8mm diameter was provided which was connected to a peristaltic pump, through 0.25 inch check valve and silicon tubing arrangement for pumping the feed. This 8mm diameter was enough to avoid clogging in the inlet pipe due to biomass in the feed. The inlet pipe opens towards the bottom of the reactor, so the feed strikes at the bottom and helps in uniform mixing in the system. Just over the packing media a collection tube of 0.25 inch was connected to collect the processed effluent. In order to determine the sludge concentration profile over the reactor height, the reactor was fixed with four brass sampling ports each of 0.25 inch.

2.5. Packing media

Two fixed screens at a gap of 15 cm and at a distance of 14.5 cm from the top of the reactor were fixed. The gap between these screens was filled with packing media of Polypropylene rings having a diameter of 3.6 cm.

2.6. Gas collection set-up

Gas is collected through the gas vent opening provided at top of the reactor. Amount of gas displaced is collected in the brine solution bottle. This collected gas will cause rise in liquid level in the liquid displacement jar indicating the amount of gas that has been produced in the reactor.

3. Start-up phase of the reactor

The start-up period of an anaerobic reactor is directly proportional to the concentration of the microbial population (Nandy and Kaul, 2001). Anaerobic seed culture collected from a reactor treating sago mill wastewater was used for the inoculation in the HUASB reactor. The reactor was operated in a continuous mode of operation. The feed composition of the HUASB reactor was as follows: Glucose-1.0 g/L, NH4Cl-800 mg/L and KH2PO4-200 mg/L. COD: N: P ratio was maintained around 300:10:1. The outlet pH is found to be in the range of 7.5–7.6 indicating an active metabolism of the methanogens. Varied requirement of micronutrients such as Fe, Ni, Co, and Mo is often necessary, particularly during the start up. Substances reported as inhibitory to anaerobic digestion are ammonia nitrogen, sulphide, heavy metals, alkali and alkaline-earth metals and a wide variety of organic compounds. Higher fatty acids are potential inhibitors of anaerobic digestion (McCarty and McKinny, 1961). The best operation of anaerobic reactors can be expected when the pH is maintained near neutral (Eder and Schulz, 2006; Grady et al., 1999).

4. Operation and monitoring

Operation and monitoring will be done in order to find out the feasibility of the hybrid up-flow anaerobic sludge blanket (HUASB) reactor. In the operation phase, the reactor will be operated in continuous mode for different loading rates. The pH of the reactor will be maintained near neutral by adding necessary amount of base or acid solution.The reactor was closely monitored for parameters like pH, Volatile Fatty Acid (VFA), COD, Biogas production and its Methane content, Alkalinity during entire operation periods. The sample was collected from the outlet provided in each reactor and was analyzed immediately after collection. The flow rate, pH of influent and effluent and amount of gas generated was recorded daily. The parameters such as total and soluble COD, VFA and Alkalinity were measured.

5. Results and discussion

A laboratory scale study was conducted to investigate the performance of an Anaerobic Hybrid Reactor (AHR) for treating sago wastewater. The sago industry wastewater fed with an OLR of 0.75Kg COD/ m^3/d. The reactor was started with an initial OLR of 0.75 Kg COD/ m^3/d and a HRT of 24 hrs, further it was increased by reducing the HRT to achieve the steady state condition. The reactor was closely monitored for pH, VFA, COD, Biogas production. At the end of 120 days and 150days, Start-up was completed in HUASB reactor in the presence and absence of effective microorganisms respectively. At this start-up period the OLR was found to be 2.8 kg COD/ m^3/d for HUASB reactor in the presence of effective microorganisms and 4 kg COD/ m^3/d for HUASB reactor in the absence of effective microorganisms.

5.1. Reactor operation during start-up

After start-up of the reactor with an initial OLR of 0.75 kg COD/ m^3/d, it was loaded with increasing OLR and reducing the HRT. At each OLR, the reactors were operated continuously so as to reach steady state conditions. Effluent pH and methane production remained relatively constant. The pH of the outlet stream during start-up days varied from 6-7 for HUASB and UASB reactors. This indicates that acid fermentation phase is always more rapid than that of methanogenic phase. The increase in pH was due to conversion of stronger VFA to weaker acids and the observed VFA level at the outlet was low. The alkalinity was increased in both the reactors when loading rates were increased.

Both the reactors were maintained for a period of 15 days in the same loading rate and removal efficiencies in terms of COD and TSS was 74%and 69% for ZHUASB reactor as compared with UASB of 46% and 45% during start-up days. During the stepped increase of OLR, the removal efficiency of TSS and COD was gradually increased (as to the studies supported by Karamany et al 2011). The gas production was increased with increased OLR. The maximum gas production of 1.8 L/d and 1.0 L/d for HUASB reactor in the presence of effective microorganisms and HUASB reactor in the absence of effective microorganisms were obtained.

5.2. Performance of HUASB reactor- after start-up

After achieving the start-up at an OLR of 2.2 kg/m^3/day the reactor was further loaded with increasing OLR to assess the optimum loading rate of the reactor. The HUASB reactor in the presence of (EM) start up took 120 days while the HUASB reactor in the absence of (EM) took 150 days. Increase in pH was achieved during the startup period in both the reactors but in HUASB in the presence of(EM) the highest pH was attained on 90th day of reactor operation compared to

HUASBreactor in the absence of EM) which attained on 120th day of reactor operation. Neutral pH level in the treated effluent was the indication of healthy anaerobic environment and satisfactory methanogenic activity.

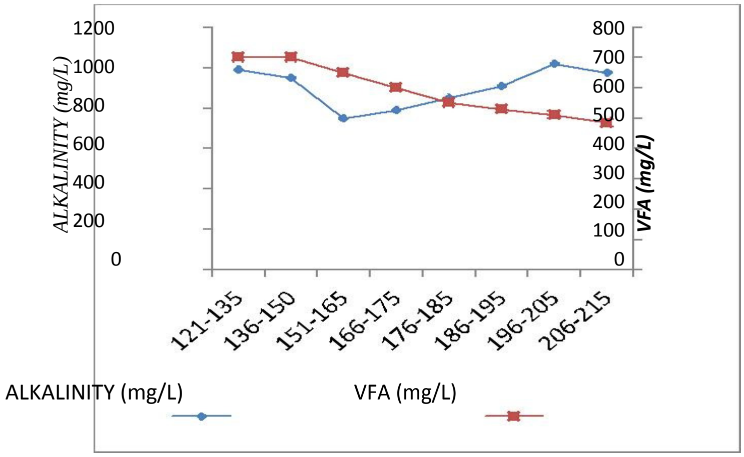

Fig. 2. Variations of VFA & Alkalinity for HUASB reactor in the presence of effective microorganisms

The maximum COD and TSS removal efficiencies were as high as 84% and 77% in HUASB reactor as compared with UASB reactor of 76% and 68% respectively during the steady state period shown in figure 4 and 5. The biogas productions with respect to time period for both reactors are shown in figure 6. The gas production was increased with increased OLR. The maximum gas production of 2.8 L/d and 2.0 L/d for HUASB reactor in the presence of effective microorganisms and HUASB reactor in the absence of effective microorganisms were obtained.

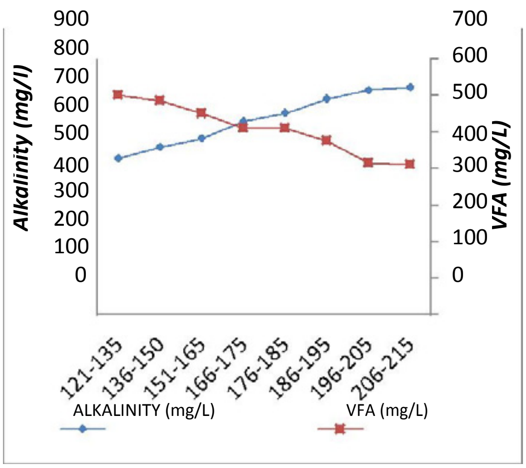

Fig. 3. Variations of VFA & Alkalinity for HUASB reactor in the absence of effective microorganisms

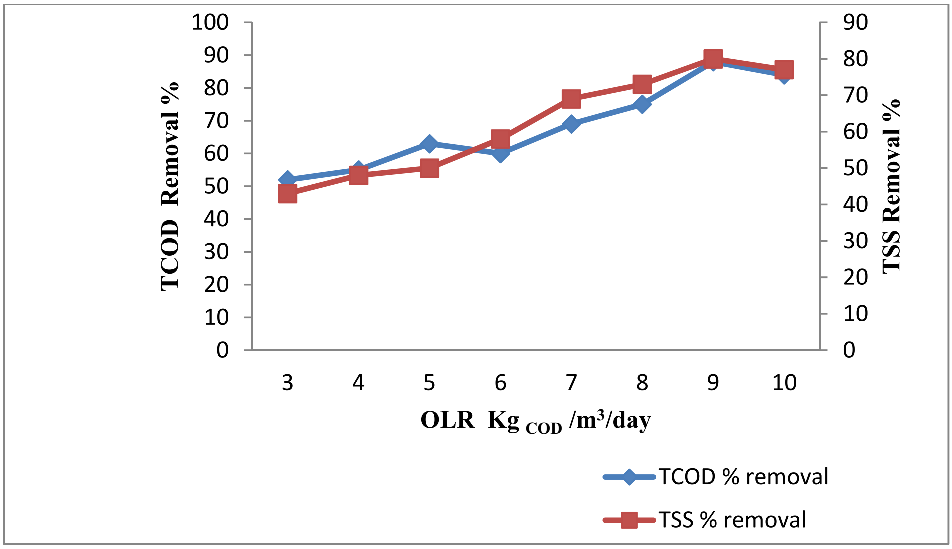

Fig. 4. Variation of COD and TSS removal % in the presence of effective microorganisms

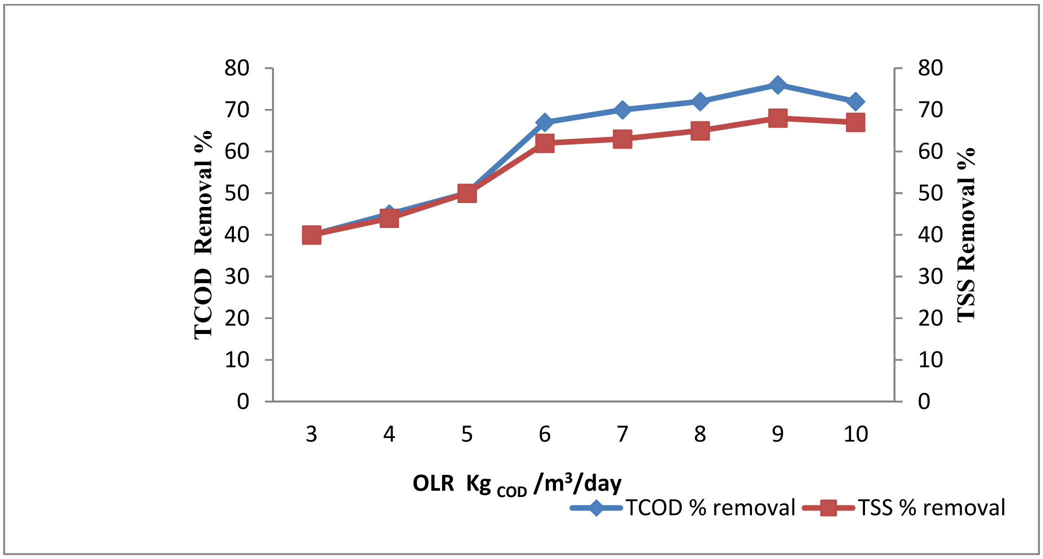

Fig. 5. Variation of COD and TSS removal% in the absence of effective microorganisms

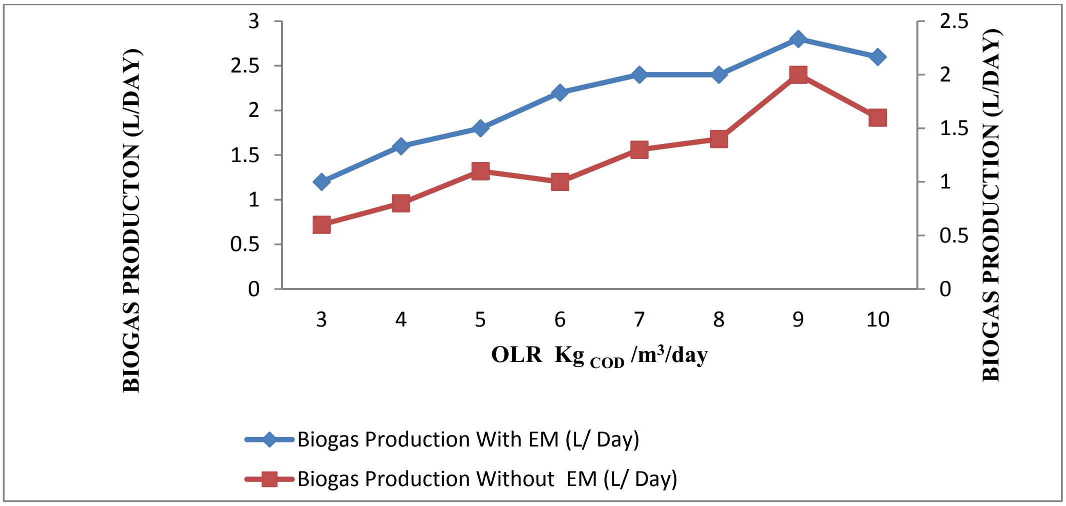

Fig. 6. Variation of Biogas production in the Presence and the Absence of Effective Microorganisms

Table 2. Operational Parameters and Treatment Efficiency of HUASB reactor at Steady State after Start-up-In the presence of effective microorganisms

Sr. No.	Days	HRT H	Influent TCOD mg/ L	OLR Kg COD/m^3 /Day	Influent Ph	Effluent pH	Alkalinity (mg/L)	TCOD % removal	TSS % removal	Biogas Production L/ Day	CH_4 Content %
1	121-135	10	925	3	4.63	6.84	990	52	43	1.2	52
2	136-150	10	1233	4	4.58	6.76	950	55	48	1.6	54
3	150-165	10	1500	5	4.60	6.92	750	63	50	1.8	55
4	166-175	10	1880	6	4.55	6.98	790	60	58	2.2	60
5	176-185	10	2000	7	4.58	7.13	850	69	69	2.4	75
6	186-195	10	2500	8	4.59	7.22	910	75	73	2.4	75
7	196-205	10	3000	9	4.60	7.42	1020	88	80	2.8	80
8	206-215	10	3650	10	4.62	7.16	975	84	77	2.6	78

Table 3. Operational Parameters and Treatment Efficiency of HUASB Reactor at Steady State after Start-up-In the absence of effective microorganisms

Sr. No.	Days	HRT H	Influent TCOD mg/ L	OLR Kg COD/m^3 /Day	Influent pH	Effluent pH	Alkalinity mg/L	TCOD % removal	TSS% removal	Biogas production L/L.Day	CH_4 Content %
1	121-135	10	925	3	4.63	6.12	550	40	40	0.6	50
2	136-150	10	1233	4	4.58	6.30	590	45	44	0.8	51

3	150-165	10	1500	5	4.60	6.17	620	50	50	1.1	55
4	166-175	10	1880	6	4.55	6.52	680	67	62	1.0	58
5	176-185	10	2000	7	4.58	6.62	710	70	63	1.3	65
6	186-195	10	2500	8	4.59	6.72	760	72	65	1.4	69
7	196-205	10	3000	9	4.60	6.82	790	76	68	2.0	74
8	206-215	10	3650	10	4.62	7	800	72	67	1.6	70

6. Conclusions

The study concludes that HUASB reactor in the presence of effective microorganisms is superior and a promising technology as compared to HUSAB reactor in the absence of effective microorganisms for the treatment of sago industry wastewater. The optimum HRT for HUASB reactor in the presence of (EM) and HUASB reactor in the absence of (EM) are 10h. The maximum COD, and TSS removal efficiencies were as high as 88% and 80% in HUASB reactor in the presence of (EM) with an OLR of 9kg.COD/m^3/day as compared with HUASB reactor in the absence of (EM) 76% and 68% with an OLR of 9 kg.COD/m^3/day. COD removal efficiency. EM has the potential to improve the overall effectiveness and efficiency of HUASB reactor for treatment of sago mill wastewater.

Thus the packing media (polypropylene rings) present in the HUASB reactor was able to retain high biomass concentration without any serious sludge wash out even at higher organic loading rates. Moreover, Gas-Liquid-Solid separator device need not be specially designed for HUASB reactor because the packing media itself acts as a GLS separator in HUASB hence proving the reactor to be an economically feasible one. A duration of 120 days was only required for the start-up period because of the use of Effective microorganisms as a seed. Further, the biogas generated during the process adds attraction as it can be used as a fuel.

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